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Hawkins,  
C. P.

LIVESTOCK GRAZING IMPACTS ON RIPARIAN  
& AQUATIC ECOSYSTEMS IN THE WILDERNESS  
OF THE WESTERN U.S.:SYSTHESIS OF EXISTNG  
KNOWLEDGE & RECOMMENDATIONS FOR  
RESEARCH Dr. Charles Hawkins

Final Report

Livestock grazing impacts on riparian and aquatic ecosystems in the  
wilderness of the western United States: synthesis of existing knowledge  
and recommendations for research.

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Dr. Peter Landres  
Aldo Leopold Wilderness Institute  
USDA, Forest Service  
Box 8089  
Missoula, Montana 59807

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By

Charles P. Hawkins  
Department of Fisheries and Wildlife  
Utah State University  
Logan, UT 84322-5210

## Introduction and Statement of the Problem

Livestock grazing is known to have severely degraded some stream and riparian ecosystems (Platts 1979, Skovlin 1984, Kaufmann and Krueger 1984, Armour et al. 1994, Fleischner 1994) and thus is an important concern for those responsible for the management of those wilderness areas where livestock grazing is permitted. However, development and implementation of specific management plans has been difficult for two reasons: (1) a lack of information on the effects of livestock grazing on streams and riparian ecosystems specific to wilderness areas and (2) our inability to date to derive empirical generalizations based on quantitative and replicated data regarding the effects of livestock on these ecosystems either within or outside wilderness areas. The objectives of this project were to:

1. Synthesize the literature on livestock grazing impacts to riparian and aquatic ecosystems in wilderness of the western United States.
2. Analyze the data from as many prior studies as feasible in a meta-analysis to discern broad geographic and ecological patterns in livestock grazing impacts to riparian and aquatic ecosystems of the western United States.
3. Develop a set of prioritized knowledge-gaps based upon the literature synthesis and meta-analysis.
4. Prioritize recommendations for future research on livestock grazing impacts to riparian and aquatic ecosystems of the western United States based on the literature synthesis, meta-analysis, and the set of prioritized knowledge gaps.

## Methods

Literature Search — We compiled literature regarding the effects of livestock grazing on stream and riparian ecosystems by searching a series of computerized databases:

1. MERLIN (Utah State University's main library facility),
2. Several CD ROM data bases including:
  - Fish and Wildlife Worldwide
  - Natural Resources
  - Wildlife Worldwide
  - AGRICOLA (a comprehensive database covering all aspects of agriculture and forestry),
  - Water Resources Abstracts, and
  - Index to Government Documents
3. BIOSIS (a data base containing over 8.5 million citations from Biological Abstracts and BioResearch), and
4. CAB (Commonwealth Agricultural Bureaux), a database containing citations from over 8,500 journals.

Sources identified from these searches were classified into 13 categories depending on the primary focus of the paper.

**Vegetation** studies that examined effects of grazing on riparian vegetation. Response variables included vegetation density, cover, biomass, height, production, diversity, or reproductive success.

**Wildlife** literature summarized intensity of use of riparian areas by wildlife in the presence and absence of grazing. Taxa examined included deer, elk, small mammals, reptiles, and amphibians.

**Bird** studies that examined response of birds to grazing.

**Geomorphology** literature that reported how bank stability, channel morphology, riffle/pool ratio, or substrate character varied between grazed and ungrazed streams.

**Soil** studies that examined grazing effects on soil compaction, moisture content, or chemistry.

**Water Quality** reports that typically examined how grazing affected nutrient concentrations, bacteria populations, turbidity, or suspended solids.

**Hydrology** studies that described grazing effects on stream flow, timing, or water yield.

**Fish** studies that included evaluations of fish biomass, density, community composition, production, or changes in habitat.

**Aquatic Invertebrate** studies that examined how invertebrate assemblages responded to livestock grazing.

**Livestock** studies that examined cattle or sheep nutrition or behavior as a function of habitat use.

**Wilderness Issues** that describe proposed techniques for evaluating effects of grazing on wilderness areas or evaluate effects of grazing on wilderness values.

**General Information or Policy Documents** that included descriptions of management practices, literature reviews, or qualitative summaries or reviews of the effects of grazing on riparian areas.

**Other** studies dealing with miscellaneous aspects of livestock grazing and riparian areas.

Meta-analysis — To conduct a meta-analysis, we needed to compile data from those studies that contained quantitative data into a single data file. Such a file will typically contain information on the initial design, the response variables and any covariables measured, and response variables standardized in such a way to allow direct comparisons among studies. For each of the reports examined, we extracted data on response variables from grazed and ungrazed treatments. Other treatments were sometimes included in study designs but were too infrequently used for inclusion in this review. It was also clear that the meaning of an ungrazed treatment varied from study to study. In some cases, the ungrazed treatment may have been close to having never been exposed to significant livestock grazing. In other cases, the ungrazed treatment was an area in which livestock had been excluded for several to many years. We could not examine the potentially confounding effect of length of time “ungrazed” treatments had been livestock free, and this fact represents a potentially serious limitation in our ability to generalize from the data we examined.

In addition to the meta-analysis we also conducted vote counting analyses to determine to the frequency of studies in which livestock grazing had significant effects on response variables. In this analysis, we used 3 measures of significance following Feminella and Hawkins (1995). First we tallied the number of studies in which the authors reported differences between grazed and ungrazed treatments to be statistically significant ( $P < 0.05$ ). Second, we calculated the difference between treatments and assumed differences  $> 1.5X$  to be ecologically significant. Third, we tallied the number of studies in which trends (the direction of response) between treatments either agreed or disagreed with expectations based on our understanding of conventional wisdom.

## Results

Of the thousands of articles searched, we found 245 sources that contained relevant information potentially useful to our study (Appendix A). The focus of these studies varied considerably and were not uniformly distributed among the categories we examined (Fig. 1). The most frequently encountered type of study was that dealing with general riparian management or policy issues. The most frequently encountered studies that contained quantitative data were those examining responses of riparian vegetation, wildlife, birds, and stream geomorphology to livestock grazing. Fewer papers contained data that dealt with soils, hydrology, water quality, fish and aquatic invertebrates. Several papers contained data describing livestock nutritional and behavioral responses, whereas very few dealt with wilderness issues.

Of the reports we examined only 25 studies contained quantitative data of sufficient rigor for use in a meta-analysis (Appendix B). Because some studies examined more than 1 response variable, these 25 studies reported 98 different contrasts in response variables between grazed and ungrazed treatments (Fig. 2). Although sample sizes were generally high enough within some categories to allow a meta-analysis, the

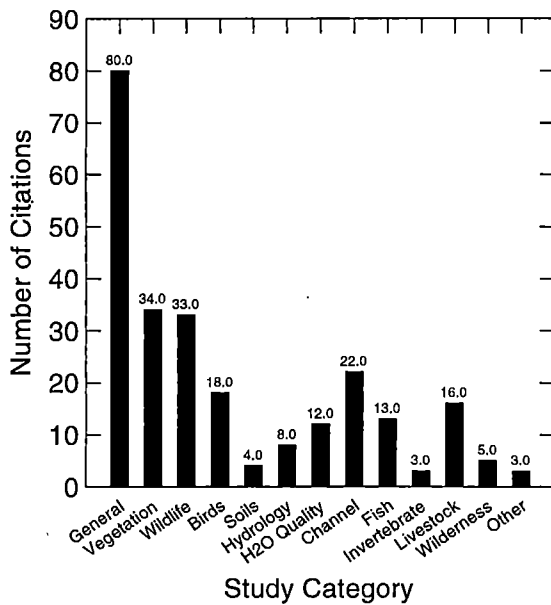


Fig. 1. Number of studies dealing with different aspects of livestock grazing and riparian ecosystems. Some papers contained data on more than one type of response variable.

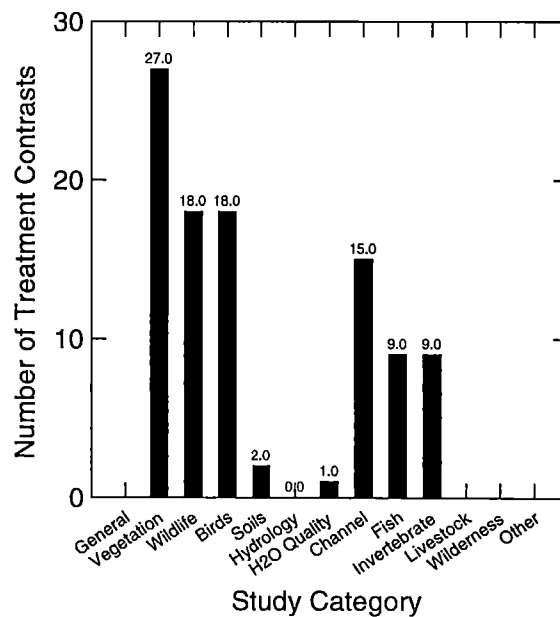


Fig. 2. Number of treatment contrasts (grazed versus nongrazed) extracted from sources in Fig. 1.

specific measures used within each category of response variable varied markedly (Table 1). We therefore concluded that inferences derived from such an analysis, even after data standardization, would be of doubtful use and likely misleading.

## General Patterns

Few clear trends emerged from the compiled data with respect to magnitude of response to grazing or direction of trends (Appendix B). Only 10 of the contrasts included tests of statistical significance of the results and of those that did, 4 reported significant ( $P < 0.05$ ) differences between grazed and ungrazed treatments and 6 contrasts were not significantly different. Many of the differences between treatments were potentially too small to be detected by typical statistical tests had they been applied with 61% of contrasts reporting less than a 1.5 fold difference between grazed and ungrazed treatments. Furthermore, in only 59% of the contrasts were trends (direction of response to grazing) consistent with expectations based on our general understanding of how livestock should affect stream and riparian ecosystems.

Table 1. Measures used in reporting results of studies for each response variable.

Response Category	Variables Measured	Number of Contrasts	Response Category	Variables Measured	Number of Contrasts
Vegetation	Density (4 measures)	11	Soils	% Organic Matter	1
	Volume	4		Phosphorus	1
	Diversity (H')	5			
	Richness	5			
Wildlife	Density	3	Water Quality	21 Variables	1
	Catch per effort	3			
	Numbers	1			
	H'	5			
	Richness	6			
Birds	Density (2 measures)	4	Fish	Biomass (3 measures)	5
	Number	2		Density (2 measures)	3
	H'	6		Relative Density	1
	Richness	6			
Channel	Pool Abundance	1	Aquatic Invertebrates	Biomass	1
	% Riffle	1		Density	2
	Pool Volume	3		H'	2
	Width/Depth	6		Richness	2
	% Fine Sediment	4		Biotic Condition Index	1

Table 2. Number of contrasts with difference between treatments > 1.5 X or not and number of contrasts agreeing or disagreeing with expected trends.

> 1.5X?	Vegetation	Wildlife	Birds	Channel
Y	13	7	6	3
N	14	11	12	12
	Soil	Water Qual.	Fish	Aquatic Invert.
Y	2	0	6	2
N	0	1	3	7
Expected Trend?	Vegetation	Wildlife	Birds	Channel
Y	16	14	6	9
N	11	3	12	6
	Soil	Water Qual.	Fish	Aquatic Invert.
Y	2	ND	7	4
N	0	ND	2	5

Although sample sizes within any single category of response variable were too small to draw definitive conclusions, some categories appeared to respond more strongly to grazing than others (Table 2). Also, overall responses of some categories tended to agree with expectations whereas responses for other categories tended to be inconsistent with expectations (Table 2). Few bird, aquatic invertebrate, and channel contrasts showed differences of 1.5-fold or greater, whereas 67% of fish measures did. The general trend within bird studies was for responses to be opposite that expected, i.e., richness or abundance often was higher in the grazed treatment. In contrast, the trend within channel and wildlife studies generally agreed with expectations: e.g., channel width-depth ratios were higher in grazed areas and wildlife richness or abundance was usually lower in grazed areas.

## Discussion

Objective 1. Synthesize the literature on livestock grazing impacts to riparian and aquatic ecosystems in wilderness of the western United States.

It was apparent from this study that we cannot yet generalize with confidence about the effects livestock grazing have on riparian ecosystems as a whole. The extant literature provides glimpses of how a variety of different variables measured in different ways respond to grazing under different environmental settings, but the lack of truly replicated studies or studies comparing similar treatments over a range of settings prohibits drawing even qualitative inferences in most cases. As a consequence our understanding of, and hence ability to predict, the effects livestock grazing will have on riparian ecosystems in wilderness areas is extremely limited.

Objective 2. Analyze the data from as many prior studies as feasible in a meta-analysis to discern broad geographic and ecological patterns in livestock grazing impacts to riparian and aquatic ecosystems of the western United States.

Although natural resource managers have been interested in the effects of livestock grazing on riparian ecosystems for over 3 decades and thousands of papers and reports have been published on this issue, quantitative data from well designed studies are sorely lacking. This lack of quantitative data measured in standard ways precluded conducting meta-analyses, which have been so useful in other areas of science in increasing our overall understanding of interactions and processes that individual studies can seldom elucidate.

Objective 3. Develop a set of prioritized knowledge-gaps based upon the literature synthesis and meta-analysis.

The majority of studies on effects of livestock grazing have focused on wildlife (36 contrasts including birds) and vegetation (27 contrasts) responses. These relatively sample sizes notwithstanding, clear generalizations did not emerge from the literature we examined suggesting that responses may be somewhat specific to different types of



environmental settings. We could not evaluate this hypothesis however, because too little information was provided in most reports for us to examine how responses varied to livestock grazing under different climatic, geologic, and ecological conditions. We strongly suspect that such studies will be required before any clarity emerges, however a coordinated effort with a considerable investment in time and resources will almost certainly be needed on the part of natural resource management agencies to address the current inadequate state of our knowledge.

Objective 4. Prioritize recommendations for future research on livestock grazing impacts to riparian and aquatic ecosystems of the western United States based on the literature synthesis, meta-analysis, and the set of prioritized knowledge gaps.

The availability of quantitative data from which we might predict how specific riparian ecosystems will respond to livestock grazing is so meager that it is premature to prioritize research needs. Rankings would almost certainly differ depending on region and specific management challenges. Considering the values that we manage for in wilderness areas, it seems clear however that studies that focus on effects of livestock on both the aesthetic nature of riparian ecosystems and their ability to support high biodiversity and water quality are critically needed. Considering that these 2 broad areas encompass most of the categories of variables reviewed here, it seems a prudent research strategy to adopt in both wilderness and non-wilderness areas would be to design standardized, synoptic, and holistic studies that could be conducted in several settings thus providing both sorely needed replication as well as data on overall ecosystem responses. Such a research effort would have significant initial costs, but the long-term cost of such an approach would be modest in terms of the information gained and hence our ability to devise more objective management plans for livestock in riparian areas.

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## Appendix A

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Appendix B. Summary of data from studies examining the effects of livestock grazing on different attributes of riparian ecosystems. Sources of data are keyed by reference number as listed in Appendix A.

Ref#	Year	Site	Treatment	Variable	Measure	Units	Species or subcategory	Result	Stat Sig?	1.5x?	E/O
13098	1982	South Platte River	Ungrazed	Birds	Density	100/ha	All birds	71.54			
13098	1982	South Platte River	Grazed	Birds	Density	100/ha	All birds	69.23		N	E
13560	1978-1979	Catherine Creek	Ungrazed	Birds	Density	#/ha	Kentucky bluegrass-mixed forbs	6.67			
13560	1978-1979	Catherine Creek	Grazed	Birds	Density	#/ha	Kentucky bluegrass-mixed forbs	10.17		Y	O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	Density	#/ha	Douglas Hawthorne-kentucky bluegrass	11.30			
13560	1978-1979	Catherine Creek	Grazed	Birds	Density	#/ha	Douglas Hawthorne-kentucky bluegrass	16.50		N	O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	Density	#/ha	Black cottonwood-mixed conifer	14.00			
13560	1978-1979	Catherine Creek	Grazed	Birds	Density	#/ha	Black cottonwood-mixed conifer	27.17		Y	O
13563	1989	Summit Creek	Ungrazed	Birds	H'			2.52			
13563	1989	Summit Creek	Grazed	Birds	H'			4.07		Y	O
13554	1959-1961	South Platte River	Ungrazed	Birds	H'			0.35			
13554	1959-1961	South Platte River	Grazed	Birds	H'			0.47		N	O
13569	1978	Upper Gunnison	Ungrazed	Birds	H'		Male based	1.69			
13569	1978	Upper Gunnison	Grazed	Birds	H'		Male based	1.81		N	O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	H'		Kentucky bluegrass-mixed forbs	1.53			
13560	1978-1979	Catherine Creek	Grazed	Birds	H'		Kentucky bluegrass-mixed forbs	1.31		N	E
13560	1978-1979	Catherine Creek	Ungrazed	Birds	H'		Douglas Hawthorne-kentucky bluegrass	1.85			
13560	1978-1979	Catherine Creek	Grazed	Birds	H'		Douglas Hawthorne-kentucky bluegrass	2.02		N	O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	H'		Black cottonwood-mixed conifer	1.58			
13560	1978-1979	Catherine Creek	Grazed	Birds	H'		Black cottonwood-mixed conifer	2.03		N	O
13570	1985-1986	Rio de las Vacas	Ungrazed	Birds	Number			835.00			
13570	1985-1986	Rio de las Vacas	Grazed	Birds	Number			500.50		Y	E
13569	1978	Upper Gunnison	Ungrazed	Birds	Number			39.56			
13569	1978	Upper Gunnison	Grazed	Birds	Number			31.17		N	E
13570	1985-1986	Rio de las Vacas	Ungrazed	Birds	S			44.75			
13570	1985-1986	Rio de las Vacas	Grazed	Birds	S			35.00		N	E
13563	1989	Summit Creek	Ungrazed	Birds	S			4.00			
13563	1989	Summit Creek	Grazed	Birds	S			7.00		Y	O
13569	1978	Upper Gunnison	Ungrazed	Birds	S			10.67			
13569	1978	Upper Gunnison	Grazed	Birds	S			11.95		N	O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	S		Kentucky bluegrass-mixed forbs	8.50			
13560	1978-1979	Catherine Creek	Grazed	Birds	S		Kentucky bluegrass-mixed forbs	8.17		N	E

Ref#	Year	Site	Treatment	Variable	Measure	Units	Species or subcategory	Result	Stat Sig?	1.5x?	E/O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	S		Douglas Hawthorne-kentucky bluegrass	8.83			
13560	1978-1979	Catherine Creek	Grazed	Birds	S		Douglas Hawthorne-kentucky bluegrass	11.67		N	O
13560	1978-1979	Catherine Creek	Ungrazed	Birds	S		Black cottonwood-mixed conifer	8.67			
13560	1978-1979	Catherine Creek	Grazed	Birds	S		Black cottonwood-mixed conifer	13.67		Y	O
13094	1983-1984	Rio de las Vacas	Ungrazed	Bugs	BCI			79.00			
13094	1983-1984	Rio de las Vacas	Grazed	Bugs	BCI			68.50		N	E
13094	1983	Rio de las Vacas	Ungrazed	Bugs	Biomass	g/sq m	All bugs	764.70			
13094	1983	Rio de las Vacas	Grazed	Bugs	Biomass	g/sq m	All bugs	1110.76		Y	O
13663	1975	Big Creek	Ungrazed	Bugs	H'		Macroinvertebrate	1.97			
13663	1975	Big Creek	Grazed	Bugs	H'		Macroinvertebrate	2.09		N	O
13094	1983-1984	Rio de las Vacas	Ungrazed	Bugs	H'			2.86			
13094		Rio de las Vacas	Grazed	Bugs	H'			3.63		N	O
13663	1975	Big Creek	Ungrazed	Bugs	Number	#/sq m	Macroinvertebrate	41347.00			
13663	1975	Big Creek	Grazed	Bugs	Number	#/sq m	Macroinvertebrate	38752.00		N	O
13094	1983-1984	Rio de las Vacas	Ungrazed	Bugs	Number	#/sq m	All bugs	959.30			
13094	1983-1984	Rio de las Vacas	Grazed	Bugs	Number	#/sq m	All bugs	1958.00		Y	E
13663	1975	Big Creek	Ungrazed	Bugs	S		Macroinvertebrate	29.30			
13663	1975	Big Creek	Grazed	Bugs	S		Macroinvertebrate	28.00		N	E
13094	1983-1984	Rio de las Vacas	Ungrazed	Bugs	S		Major groups	58.00			
13094	1983-1984	Rio de las Vacas	Grazed	Bugs	S		Major groups	60.00		N	O
13094	1983-1984	Rio de las Vacas	Ungrazed	Bugs	TQ			69.25			
13094	1983-1984	Rio de las Vacas	Grazed	Bugs	TQ			79.50		N	E
802	1978	Wstrn Washington	Ungrazed	Fish	Biomass	g/sq m	All Salmonids	3.64			
802	1978	Wstrn Washington	Grazed	Fish	Biomass	g/sq m	All Salmonids	3.75		N	O
12973	1983-1984	Sheep Creek	Ungrazed	Fish	Biomass	kg/ha	All Trout	159.00			
12973	1983-1984	Sheep Creek	Grazed	Fish	Biomass	kg/ha	All Trout	76.50		Y	E
13562	1964-1968	Rock Creek	Ungrazed	Fish	Biomass	kg/ha		238.83			
13562	1964-1968	Rock Creek	Grazed	Fish	Biomass	kg/ha		71.04		Y	E
13562	1969	Rock Creek	Ungrazed	Fish	Biomass	kg/ha	All Fish	375.37			
13562	1969	Rock Creek	Grazed	Fish	Biomass	kg/ha	All Fish	88.41		Y	E
12974	1982	Rio de las Vacas	Ungrazed	Fish	Number	#/50 m	All Fish	151.70			
12974	1982	Rio de las Vacas	Grazed	Fish	Number	#/50 m	All Fish	354.80		Y	O
12974	1982	Rio de las Vacas	Ungrazed	Fish	Biomass	g/50 m	All Fish	2858.70			
12974	1982	Rio de las Vacas	Grazed	Fish	Biomass	g/50 m	All Fish	2364.50		N	E
12973	1983-1984	Sheep Creek	Ungrazed	Fish	Density	%	Rel. Abundance, All Trout	96.50			

Ref#	Year	Site	Treatment	Variable	Measure	Units	Species or subcategory	Result	Stat Sig?	1.5x?	E/O
12973	1983-1984	Sheep Creek	Grazed	Fish	Density	%	Rel. Abundance, All Trout	85.00		N	E
13562	1964-1968	Rock Creek	Ungrazed	Fish	Density	#/ha		4645.00			
13562	1964-1968	Rock Creek	Grazed	Fish	Density	#/ha		1733.00		Y	E
13562	1969	Rock Creek	Ungrazed	Fish	Density	#/ha	All Fish	5373.00			
13562	1969	Rock Creek	Grazed	Fish	Density	#/ha	All Fish	2639.00		Y	E
13562	1967	Rock Creek	Ungrazed	Geom	Pools	#/km	Before flood	34.00			
13562	1967	Rock Creek	Grazed	Geom	Pools	#/km	Before flood	23.40		N	E
802	1978	Wstrn Washington	Ungrazed	Geom	Riffle	%		43.00			
802	1978	Wstrn Washington	Grazed	Geom	Riffle	%		38.00	N	N	O
12576	1991	Coyote Valley Crk	Ungrazed	Geom	Surface fines	%	Pools only	40.50			
12576	1991	Coyote Valley Crk	Grazed	Geom	Surface fines	%	Pools only	26.90		N	O
12576	1991	Silver King Creek	Ungrazed	Geom	Surface fines	%	Riffles only	9.00			
12576	1991	Silver King Creek	Grazed	Geom	Surface fines	%	Riffles only	15.10		N	E
13068	1984	Cherry Creek	Ungrazed	Geom	Surface fines	%	Silt substrate	13.00			
13068	1984	Cherry Creek	Grazed	Geom	Surface fines	%	Silt substrate	22.00	Y	Y	E
802	1978	Wstrn Washington	Ungrazed	Geom	Surface fines	%	Sand or finer	32.00			
802	1978	Wstrn Washington	Grazed	Geom	Surface fines	%	Sand or finer	40.50	N	N	E
12576	1991	Coyote Valley Crk	Ungrazed	Geom	Volume	m cubed	Pools only - residual	2.20			
12576	1991	Coyote Valley Crk	Grazed	Geom	Volume	m cubed	Pools only - residual	3.20		N	O
12576	1991	Silver King Creek	Ungrazed	Geom	Volume	m cubed	Pools only - residual	46.00			
12576	1991	Silver King Creek	Grazed	Geom	Volume	m cubed	Pools only - residual	54.00		N	O
802	1978	Wstrn Washington	Ungrazed	Geom	Volume	m cubed	Pool, glide	21.00			
802	1978	Wstrn Washington	Grazed	Geom	Volume	m cubed	Pool, glide	25.50	N	N	O
12576	1991	Coyote Valley Crk	Ungrazed	Geom	W/D	m		3.25			
12576	1991	Coyote Valley Crk	Grazed	Geom	W/D	m		7.30		Y	E
12576	1991	Silver King Creek	Ungrazed	Geom	W/D	m		18.40			
12576	1991	Silver King Creek	Grazed	Geom	W/D	m		22.05		N	E
13562	1968	Rock Creek	Ungrazed	Geom	W/D	m		19.40			
13562	1968	Rock Creek	Grazed	Geom	W/D	m		28.50		N	E
13068	1984	Cherry Creek	Ungrazed	Geom	W/D	m		28.00			
13068	1984	Cherry Creek	Grazed	Geom	W/D	m		37.00	Y	N	E
12973	1984	Sheep Creek	Ungrazed	Geom	W/D	m		18.50			
12973	1984	Sheep Creek	Grazed	Geom	W/D	m		55.00		Y	E
13663	1975	Big Creek	Ungrazed	Geom	W/D	ft		0.07			
13663	1975	Big Creek	Grazed	Geom	W/D	ft		0.04		N	O

Ref#	Year	Site	Treatment	Variable	Measure	Units	Species or subcategory	Result	Stat Sig?	1.5x?	E/O
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	Density	#/ha	Kentucky bluegrass-mixed forbs	316.50			
13560	1978-1979	Catherine Creek	Grazed	Mammals	Density	#/ha	Kentucky bluegrass-mixed forbs	247.50		N	E
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	Density	#/ha	Douglas Hawthorne-kentucky bluegrass	344.70			
13560	1978-1979	Catherine Creek	Grazed	Mammals	Density	#/ha	Douglas Hawthorne-kentucky bluegrass	304.30		N	E
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	Density	#/ha	Black cottonwood-mixed conifer	196.30			
13560	1978-1979	Catherine Creek	Grazed	Mammals	Density	#/ha	Black cottonwood-mixed conifer	73.00		Y	E
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	H'		Kentucky bluegrass-mixed forbs	0.48			
13560	1978-1979	Catherine Creek	Grazed	Mammals	H'		Kentucky bluegrass-mixed forbs	0.71		N	O
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	H'		Douglas Hawthorne-kentucky bluegrass	0.62			
13560	1978-1979	Catherine Creek	Grazed	Mammals	H'		Douglas Hawthorne-kentucky bluegrass	0.03		Y	E
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	H'		Black cottonwood-mixed conifer	1.03			
13560	1978-1979	Catherine Creek	Grazed	Mammals	H'		Black cottonwood-mixed conifer	0.52		Y	E
13559	1977	Medicine Lodge	Ungrazed	Mammals	H'		Small Mammals	1.53			
13559	1977	Medicine Lodge	Grazed	Mammals	H'		Small Mammals	1.29		N	E
13559	1974	Big Hole Mtns	Ungrazed	Mammals	H'		Small Mammals	1.70			
13559	1974	Big Hole Mtns	Grazed	Mammals	H'		Small Mammals	1.97		N	O
13570	1985	Rio de las Vacas	Ungrazed	Mammals	Number		Small mammals	91.75			
13570	1985	Rio de las Vacas	Grazed	Mammals	Number		Small mammals	38.50		Y	E
13559	1977	Medicine Lodge	Ungrazed	Mammals	Number	#/100 trap nights	Small Mammals	8.00			
13559	1977	Medicine Lodge	Grazed	Mammals	Number	#/100 trap nights	Small Mammals	6.00		N	E
13559	1974	Big Hole Mtns	Ungrazed	Mammals	Number	#/100 trap nights	Small Mammals	58.80			
13559	1974	Big Hole Mtns	Grazed	Mammals	Number	#/100 trap nights	Small Mammals	20.50		Y	E
13570	1985	Rio de las Vacas	Ungrazed	Mammals	S			7.25			
13570	1985	Rio de las Vacas	Grazed	Mammals	S			5.00		N	E
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	S		Kentucky bluegrass-mixed forbs	2.25			
13560	1978-1979	Catherine Creek	Grazed	Mammals	S		Kentucky bluegrass-mixed forbs	2.25		N	
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	S		Douglas Hawthorne-kentucky bluegrass	3.00			
13560	1978-1979	Catherine Creek	Grazed	Mammals	S		Douglas Hawthorne-kentucky bluegrass	1.67		Y	E
13560	1978-1979	Catherine Creek	Ungrazed	Mammals	S		Black cottonwood-mixed conifer	3.33			
13560	1978-1979	Catherine Creek	Grazed	Mammals	S		Black cottonwood-mixed conifer	2.67		N	E
13559	1977	Medicine Lodge	Ungrazed	Mammals	S		Small Mammals	42.60			
13559	1977	Medicine Lodge	Grazed	Mammals	S		Small Mammals	36.90		N	E
13559	1974	Big Hole Mtns	Ungrazed	Mammals	S		Small Mammals	8.00			
13559	1974	Big Hole Mtns	Grazed	Mammals	S		Small Mammals	10.00		N	O
13570	1985	Rio de las Vacas	Ungrazed	Reptiles	Number		Snakes	144.50			



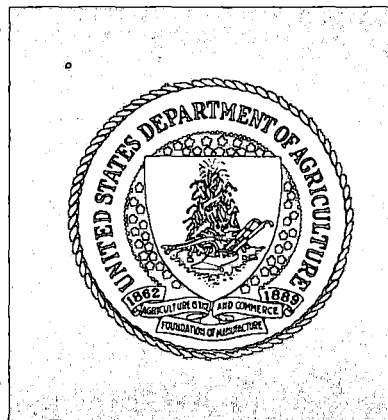
Ref#	Year	Site	Treatment	Variable	Measure	Units	Species or subcategory	Result	Stat Sig?	1.5x?	E/O
13570	1985	Rio de las Vacas	Grazed	Reptiles	Number		Snakes	15.00		Y	E
13562	1964-1968	Rock Creek	Ungrazed	Soils	Organic Matter	%	0-40 cm	6.20			
13562	1964-1968	Rock Creek	Grazed	Soils	Organic Matter	%	0-40 cm	0.64		Y	E
13562	1964-1968	Rock Creek	Ungrazed	Soils	Phosphorus	mg/l	0-40 cm	4.50			
13562	1964-1968	Rock Creek	Grazed	Soils	Phosphorus	mg/l	0-40 cm	2.06		Y	E
13061	1981-1983	Empire Creek	Ungrazed	Veg	Biomass	kg/ha		5835.00			
13061	1981-1983	Empire Creek	Grazed	Veg	Biomass	kg/ha		3861.00		Y	E
13570	1985-1986	Rio de las Vacas	Ungrazed	Veg	Cover	rel. %	Herbaecous plants	54.50			
13570	1985-1986	Rio de las Vacas	Grazed	Veg	Cover	rel. %	Herbaecous plants	65.60		N	O
13564		Bitterroot River	Ungrazed	Veg	Cover	%	Canopy	29.20			
13564		Bitterroot River	Grazed	Veg	Cover	%	Canopy	34.70	N	N	O
13570	1985-1986	Rio de las Vacas	Ungrazed	Veg	Density	#/250 sq m	All trees	8.50			
13570	1985-1986	Rio de las Vacas	Grazed	Veg	Density	#/250 sq m	All trees	0.30		Y	E
13570	1985-1986	Rio de las Vacas	Ungrazed	Veg	Density	#/250 sq m	All shrubs	6.70			
13570	1985-1986	Rio de las Vacas	Grazed	Veg	Density	#/250 sq m	All shrubs	0.20		Y	E
13062	1975-1983	Meadow Creek	Ungrazed	Veg	Density	lbs/acre	Grasses	1294.00			
13062	1975-1983	Meadow Creek	Grazed	Veg	Density	lbs/acre	Grasses	1525.00		Y	O
13062	1975-1983	Meadow Creek	Ungrazed	Veg	Density	lbs/acre	Forbs	186.00			
13062	1975-1983	Meadow Creek	Grazed	Veg	Density	lbs/acre	Forbs	362.00		Y	O
13562	1964-1968	Rock Creek	Ungrazed	Veg	Density		Cottonwoods > 1 m	2.40			
13562	1964-1968	Rock Creek	Grazed	Veg	Density		Cottonwoods > 1 m	1.60		Y	E
13562	1964-1968	Rock Creek	Ungrazed	Veg	Density		Tall Shrubs > 1 m	5.70			
13562	1964-1968	Rock Creek	Grazed	Veg	Density		Tall Shrubs > 1 m	0.70		Y	E
13562	1964-1968	Rock Creek	Ungrazed	Veg	Density		Low Shrubs < 1 m	24.50			
13562	1964-1968	Rock Creek	Grazed	Veg	Density		Low Shrubs < 1 m	1.90		Y	E
13667	1960-1978	South Platte	Ungrazed	Veg	Density	#/ac	All Trees	50.80			
13667	1960-1978	South Platte	Grazed	Veg	Density	#/ac	All Trees	42.90		N	E
13667	1960-1978	South Platte	Ungrazed	Veg	Density	#/ac	Cottonwood	40.30			
13667	1960-1978	South Platte	Grazed	Veg	Density	#/ac	Cottonwood	28.80		N	E
13667	1960-1978	South Platte	Ungrazed	Veg	Density	#/ac	Willow	10.50			
13667	1960-1978	South Platte	Grazed	Veg	Density	#/ac	Willow	14.20		N	O
13552	1965-1967	South Dakota	Ungrazed	Veg	H'			2.86			
13552	1965-1967	South Dakota	Grazed	Veg	H'			3.63		N	O
13089	1976	Elk City, Idaho	Ungrazed	Veg	H'		Moist	2.73			
13089	1976	Elk City, Idaho	Grazed	Veg	H'		Moist	2.46		N	E

Ref#	Year	Site	Treatment	Variable	Measure	Units	Species or subcategory	Result	Stat Sig?	1.5x?	E/O
13089	1976	Elk City, Idaho	Ungrazed	Veg	H'		Wet	1.10			
13089	1976	Elk City, Idaho	Grazed	Veg	H'		Wet	1.83		Y	O
13569	1978	Gunnison	Ungrazed	Veg	H'			1.92			
13569	1978	Gunnison	Grazed	Veg	H'			3.13		N	O
12846	1988-1989	Sheep Creek	Ungrazed	Veg	H'			3.24			
12846	1988-1989	Sheep Creek	Grazed	Veg	H'			2.72		N	E
13089	1976	Elk City, Idaho	Ungrazed	Veg	S			19.00			
13089	1976	Elk City, Idaho	Grazed	Veg	S			15.00		N	E
13089	1976	Elk City, Idaho	Ungrazed	Veg	S			5.00			
13089	1976	Elk City, Idaho	Grazed	Veg	S			9.00		Y	O
13552	1965-1967	South Dakota	Ungrazed	Veg	S			27.00			
13552	1965-1967	South Dakota	Grazed	Veg	S			26.25		N	E
12846	1988-1989	Sheep Creek	Ungrazed	Veg	S			55.33			
12846	1988-1989	Sheep Creek	Grazed	Veg	S			50.00		N	E
13552	1965-1967	South Dakota	Ungrazed	Veg	S			27.00			
13552	1965-1967	South Dakota	Grazed	Veg	S			26.25		N	E
13564		Bitterroot River	Ungrazed	Veg	Volume	%	Ground cover	11.90			
13564		Bitterroot River	Grazed	Veg	Volume	%	Ground cover	7.00	N	Y	E
13564		Bitterroot River	Ungrazed	Veg	Volume	%	Bush cover	36.50			
13564		Bitterroot River	Grazed	Veg	Volume	%	Bush cover	13.60	Y	Y	E
13564		Bitterroot River	Ungrazed	Veg	Volume	%	Mid-canopy	29.10			
13564		Bitterroot River	Grazed	Veg	Volume	%	Mid-canopy	33.90	N	N	O
13564		Bitterroot River	Ungrazed	Veg	Volume	%	Canopy	22.60			
13564		Bitterroot River	Grazed	Veg	Volume	%	Canopy	45.20	Y	Y	O
13663	1975	Big Creek	Ungrazed	Water	Nitrate	mg/l	Nitrate as N	0.30			
13663	1975	Big Creek	Grazed	Water	Nitrate	mg/l	Nitrate as N	0.30		N	

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